recognized that in the case of massive MIMO, MU-MIMO transmission is critical and the challenge here is to estimate the interference due to co-scheduled UEs. That is, UE1 co-scheduled with UE2 means that both UEs are sharing a common time-frequency resource as well as Tx power when receiving data from the eNB. They receive transmission from the same eNB on the same time-frequency resource but utilizing two different precoders. These transmissions interfere with each other depending on the precoders and the channel.

[0034] Furthermore, CATT contribution R1-144948 and Intel contribution R1-144670 proposed to use beamformed CSI-RS transmission for massive MIMO. These contributions were introduced at 3GPP TSG-RAN WGI #79, November 2014. While these contributions have possible benefits, they still have the possibility of having precoding weights that can change rather quickly (e.g., dynamically) both in time and in frequency.

[0035] Rel-10 eICIC introduced a subframe subset concept, which can be considered as a type of measurement restriction. An introduction to this concept is provided in Pedersen, et al., "eICIC functionality and performance for LTE HetNet co-channel deployments", Vehicular Technology Conference (VTC Fall), 2012 IEEE. IEEE Press, 2012. The Pedersen article states the following: "It is therefore necessary for the network to configure restricted CSI measurements for Rel-10 UEs, so that the eNB receives such reports corresponding to normal subframes and ABS, respectively." That is, CSI measurements may be restricted to either normal subframes or ABSs. By contrast, in the instant embodiments, signal and interference for one CQI report (as an example) may follow different restrictions for time and/or frequency, as described below.

[0036] Exemplary embodiments herein relate to massive MIMO systems, e.g., to be deployed in 5G as well as future FD-MIMO LTE-A systems in Rel-13 and beyond. Focus is placed on the design aspects on 3D-MIMO, especially channel state information (CSI) feedback.

[0037] Channel reciprocity is one key feature of a TDD system, where an estimated channel from uplink could be used to form the beamforming precoder for a downlink transmission. It is especially interesting in a massive MIMO environment, with a large number of antenna ports, since codebook-based PMI feedback amount is too high.

[0038] In this document, exemplary solutions are proposed that are applicable to the problems noted above. Specifically, in an example, a proposal is to use measurement restrictions for CSI measurement that will enable the eNB to use UE-specific precoded CSI-RS (e.g., CSI measurement resources) for accurate MCS and rank selection for data transmission. In addition, as another example, it is proposed to use UE-specific IMRs (interference measurement resources) that are resource restricted to enable estimation of interference due to co-scheduled MU-MIMO UEs for enhancing MU-MIMO transmission. Furthermore, measurement restrictions are proposed in embodiments to be defined for CQI and RI feedback to allow for CSI-based beamforming without requiring PMI feedback.

[0039] A motivation for the exemplary embodiments herein is a need for CQI and RI feedback using precoded CSI-RS (e.g., CSI measurement resource) and in conjunction with IMRs for MU-MIMO purposes. That is, since an appropriate precoding weight can change rather quickly (e.g., dynamically) both in time and in frequency, it is necessary that a UE does not average the measurements obtained from CSI-RS or IMR instances in an unrestricted fashion in time or frequency or both. Therefore it is beneficial to have restrictions on how much a UE can average in time, frequency, or both while measuring multiple instances of precoded CSI-RS and IMR.

[0040] In this instance, since there is no need for PMI feedback, the accuracy requirement of channel estimation and interference estimation is reduced. In other words, the accuracy requirement of channel and interference estimation can be relaxed to a certain extent because the UE is not required to feedback a PMI in this case. Rank in this case is defined in an open loop sense of comparing single-port transmission with two-port transmission (with no PMI). On the other hand, due to the UE-specific nature of CSI-RS and IMR needed in this case, there is a need for more physical resources to be dedicated to CSI-RS and IMR within a serving cell, relative to without using UE-specific CSI-RS and UE-specific IMR. This is because UE-specific CSI-RS and IMR will be used, e.g., for multiple UEs, and this UE-specific CSI-RS and IMR is not used in a conventional system.

[0041] This invention, in an exemplary embodiment, allows one to configure separately measurement restrictions in time and/or frequency for CSI-RS resources and IMR. The accuracy of CQI, RI is expected to be not affected significantly, especially as more measurement samples become available to the UE as time progresses. Measurement restriction can be configured by the network (e.g., via the eNB **170**) and the UE **110** shall separately measure the signal and interference part following each measurement restriction.

[0042] Exemplary scheduling details for MU-MIMO is detailed in FIG. **2**, where it is shown how UE-specific precoded CSI-RS and UE-specific IMR can be utilized for accurate link adaption for MU-MIMO by incorporating some additional packet delay at the scheduler. A precoded CSI-RS along with a measurement restriction is considered to be UE-specific if the physical resources for the precoded CSI-RS with such a restriction are dedicated for a particular UE—this is a provisioning issue at the eNB **170**. The same rule applies to a UE-specific IMR. The UE does not know if some other UE is also measuring on the same resource. Other than this provisioning aspect, there is no unique property of a CSI-RS that makes it UE specific.

[0043] FIG. **2** shows a CSI-RS, IMR timeline **210** at the eNB **170**, such that UE-specific CSI-RS and IMR precoding are transmitted by eNB **170** at times **215-1**, **215-2**, and **215-3**. FIG. **2** also shows a non-UE-specific CSI-RS, IMR timeline **220**, illustrating times **225-1**, **225-2**, **225-3**, and **225-4** when the eNB **170** transmits the non-UE-specific CSI-RS, IMR. The eNB scheduler timeline **230** shows a time **260** at which a SU-MIMO CSI is received in response to the non-UE-specific CSI-RS, IMR transmitted by the eNB **170** at time **225-1**. For ease of reference, the other receptions by the eNB **170** in response to the times **225-2** through **225-4** are not shown. MU-MIMO prescheduling occurs at time **235-1** and the MU-MIMO scheduling occurs at time **235-2**. The additional packet delay **240** is also shown. Furthermore, at time **250**, the eNB transmits UE-specific CSI-RS that is precoded using a precoder intended for UE **110** and UE-specific IMR intended for UE110. At time **250**, the eNB also transmits precoded signals using a precoder not intended for UE110 on a resource that coincides with the UE specific IMR intended for UE110. It is noted that CSI-RS is a signal that is measured at the UE **110**. IMR, on the other hand, is not a signal but a time-frequency-resource, and the UE **110** measures the power on